AD-A172 074 DIGITAL TERRAIN ELEVATION DATA PROCESSING AT THE DEFENSE MAPPING AGENCY(U) DEFENSE MAPPING AGENCY WASHINGTON DC R B EDELEN AUG 86 1/1

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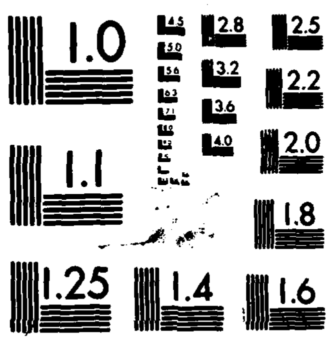

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REPORT DOCUMENTATION PAGE

1a. R[EPORT SECURITY CLASSIFICATION]	1b. RESTRICTIVE MARKINGS n/a
2a. SECURITY CLASSIFICATION AUTHORITY n/a	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for Public Release; Distribution is unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE n/a	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) n/a	5. MONITORING ORGANIZATION REPORT NUMBER(S) n/a
6a. NAME OF PERFORMING ORGANIZATION Defense Mapping Agency 6b. OFFICE SYMBOL (If applicable) PAO	7a. NAME OF MONITORING ORGANIZATION n/a
6c. ADDRESS (City, State, and ZIP Code) Washington, D.C. 20305-3000	7b. ADDRESS (City, State, and ZIP Code) n/a
8a. NAME OF FUNDING/SPONSORING ORGANIZATION DMA Hydrographic/Topographic Ctr 8b. OFFICE SYMBOL (If applicable) DPT	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER n/a
8c. ADDRESS (City, State, and ZIP Code) Washington, D.C. 20315-0030	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO.: n/a PROJECT NO.: n/a TASK NO.: n/a WORK UNIT ACCESSION NO.: n/a

DTIC ELECTE SEP 1 8 1986 S D D

11. TITLE (Include Security Classification)
Digital Terrain Elevation Data Processing at the Defense Mapping Agency

12. PERSONAL AUTHOR(S)
Edelen, Robert B.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
final	FROM ____ TO ____	1986 August	9

16. SUPPLEMENTARY NOTATION
1986 ASPRS-ACSM Fall Convention
28 Sep - 3 Oct 1986 Anchorage, Alaska

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Universal Transverse Mercator (UTM)
08			TES/EMPS

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A major product of the Defense Mapping Agency (DMA) is the digital terrain elevation matrix. This regularly spaced matrix of elevations may be presented in a geographic coordinate system in arc seconds, or in the Universal Transverse Mercator (UTM) coordinate system in meters on the ground. In July 1984, the Terrain Edit System/Elevation Matrix Processing System (TES/EMPS) was delivered to DMA. The TES/EMPS is a stand alone system which employs a combination of batch and interactive processes to perform coordinate transformations and interpolations, contour to grid processing, data merging and paneling operations, plotting, and interactive edit and quality control functions to produce elevation matrices in the final data base format. The TES/EMPS relies heavily on advanced raster graphics workstations for the generation of vector and array displays to support the aforementioned processes.

As more user applications for elevation matrices surface, the demand for greater quantity and quality of these matrices will continue to increase. This paper addresses one area (the TES/EMPS) in which advanced computer graphic, interactive processing and batch processing are

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	UNCLASSIFIED

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code)	22c. OFFICE SYMBOL
Robert B. Edelen	202-227-2608	DPT

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

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Item 19. (Continuation)

combined in a networked data processing environment to support growing production demands. The paper briefly discusses elevation matrix formats and collection systems, then discusses all phases of digital terrain elevation matrix post processing, data flows and the digital data display techniques employed to interactively evaluate and manipulate data, and stresses the importance of utilizing a variety of tools in an interactive environment to ensure the quality of elevation matrix products.

DIGITAL TERRAIN ELEVATION DATA PROCESSING AT THE DEFENSE MAPPING AGENCY

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ABSTRACT

A major product of the Defense Mapping Agency (DMA) is the digital terrain elevation matrix. This regularly spaced matrix of elevations may be presented in a geographic coordinate system in arc seconds, or in the Universal Transverse Mercator (UTM) coordinate system in meters on the ground. In July 1984, the Terrain Edit System/Elevation Matrix Processing System (TES/EMPS) was delivered to DMA. The TES/EMPS is a stand alone system which employs a combination of batch and interactive processes to perform coordinate transformations and interpolations, contour to grid processing, data merging and paneling operations, plotting, and interactive edit and quality control functions to produce elevation matrices in the final data base format. The TES/EMPS relies heavily on advanced raster graphics workstations for the generation of vector and array displays to support the aforementioned processes.

As more user applications for elevation matrices surface, the demand for greater quantity and quality of these matrices will continue to increase. This paper addresses one area (the TES/EMPS) in which advanced computer graphics, interactive processing and batch processing are combined in a networked data processing environment to support growing production demands. The paper briefly discusses elevation matrix formats and collection systems, then discusses all phases of digital terrain elevation matrix post processing, data flows and the digital data display techniques employed to interactively evaluate and manipulate data, and stresses the importance of utilizing a variety of tools in an interactive environment to ensure the quality of elevation matrix products.

BACKGROUND

In the late 1960's, DMA utilized a regularly spaced matrix of elevation data in a local table coordinate system to drive a milling machine which, in turn, automatically carved a model of the Earth's surface (May-Noma Automated Terrain Modeling, 1970). This model was then used as a mold over which plastic relief maps were formed. The elevation data used for this purpose formed a data base which was in increasing demand for a wide variety of digital applications. Early users of digital elevation data found it invaluable for land use studies and as a predictor for determining efficient placement of lines of communication. Elevation matrices were generated for portions of the lunar surface and used to generate perspective scenes (Honablew-Schlueter-Noma Software for Three Dimensional Topographic Scenes, 1982) for use in the Apollo lunar landing program. More recently, applications for digital elevation data have surfaced in advanced air and ground simulators, terrain masking for radar placement, advanced weapons systems, and in tactical simulators for mobility exercises. Digital elevation matrices are also used in the generation of analog products, such as perspective scenes and slope overlays for cross country movement analysis. As additional applications

for digital terrain elevation data surface, the flexibility, accuracy, and productivity of digital elevation data production systems will play an increasingly important role in satisfying future user requirements.

DIGITAL TERRAIN ELEVATION DATA FORMATS

Since the inception of elevation data production at DMA, the basic format has been a matrix in which elevations on the matrix correspond to regularly spaced points on the earth's surface. To satisfy varying user requirements, the elevation matrix took on different forms. Early formats were in a local table coordinate system with data spacing at one hundredth of an inch, but as additional requirements surfaced, geographic and UTM coordinate systems became predominant. Today, the primary DMA-Standard data base format is a geographic matrix where the primary unit is a 1 degree by 1 degree cell, with boundaries corresponding to geographic lines of latitude and longitude, and data spacings of 1 and 3 arc seconds. Another elevation matrix product is the FIREFINDER tape formatted in the UTM coordinate system, where the primary unit is a 100KM by 100KM square, with boundaries defined by to UTM Northings and Eastings, and data spacings of 125 meters. To a lesser degree, variations of geographic, UTM, and local table formats may be produced to satisfy specific user requirements.

ELEVATION DATA COLLECTION

Elevation data are collected at DMA from both cartographic and photographic sources. Photographic source data are collected on two types of photogrammetric instruments in either automatic or interactive modes, and cartographic source data are collected by digitizing compiled manuscripts.

Collection From Cartographic Source

Elevation data from cartographic source are collected from 1:25,000, 1:50,000 or 1:250,000 map sources from which the hypsographic features (contours, drain and ridge lines, lakes and double line drains, and supplemental elevation information) are compiled onto manuscripts. The compiled information is then digitized on the Automated Graphic Digitizing System (AGDS). The AGDS consists of a flatbed laser scanner on which information is collected at a 1 mil (0.001 inch) resolution in raster format. The raster data are then vectorized and passed to an AGDS interactive workstation where the vector data are tagged with the proper elevation, flagged with a numeric identifier (differentiating contours, drains/ridges, and supplemental elevations), reviewed, and edited to insure the quality and accuracy of the vector data. The vector data are then plotted in a final quality assurance step prior to release for processing into matrix form.

Collection From Photographic Source

UNAMACE. The Universal Automatic Map Compilation Equipment (UNAMACE) employs an automatic correlation technique, in which the elevation data are collected as a series of profiles, and output in the form of a regularly spaced matrix in a Local Space Rectangular (LSR) coordinate system. Additional information including drain, ridge, water, and control elevations may also be collected to augment the matrix data. On the UNAMACE, the collected data are reviewed on an interactive graphics workstation and edited in a final quality control step prior to post processing.

PASS. The Pooled Analytical Stereo System (PASS) is used to collect elevation data from stereo imagery using interactive techniques where the cartographer controls the Z coordinate during collection. On the PASS, the cartographer collects data in the form of a non-uniform matrix in that the data spacing along profiles is based on a timing loop and will vary with the characteristics of the terrain. As with the UNAMACE, data are collected in a LSR coordinate system, and may also be augmented with drain, ridge, water, and control elevation information.

ELEVATION DATA POST PROCESSING

The TES/EMPS

Procurement. In 1982, DMA awarded a major contract for the procurement of the Terrain Edit System/Elevation Matrix Processing System (TES/EMPS) to perform all post processing of data collected on the AGDS, UNAMACE, and PASS systems. This post processing includes all of the data manipulation and edit functions required to produce final DMA-Standard, UTM and local table formats required by users of DMA elevation matrices. The procurement goal was to provide a tool that would improve the quality and quantity of digital elevation data in response to increasing user demands, and to off-load the post processing functions from a batch oriented large mainframe environment to a dedicated interactive environment. The TES/EMPS was delivered to HTC in July 1984, and following acceptance and operational testing, began production implementation in March 1985.

TES/EMPS Hardware Configuration. The TES/EMPS is a stand alone system, which is fully dedicated to digital elevation data post processing (see Figure 1).

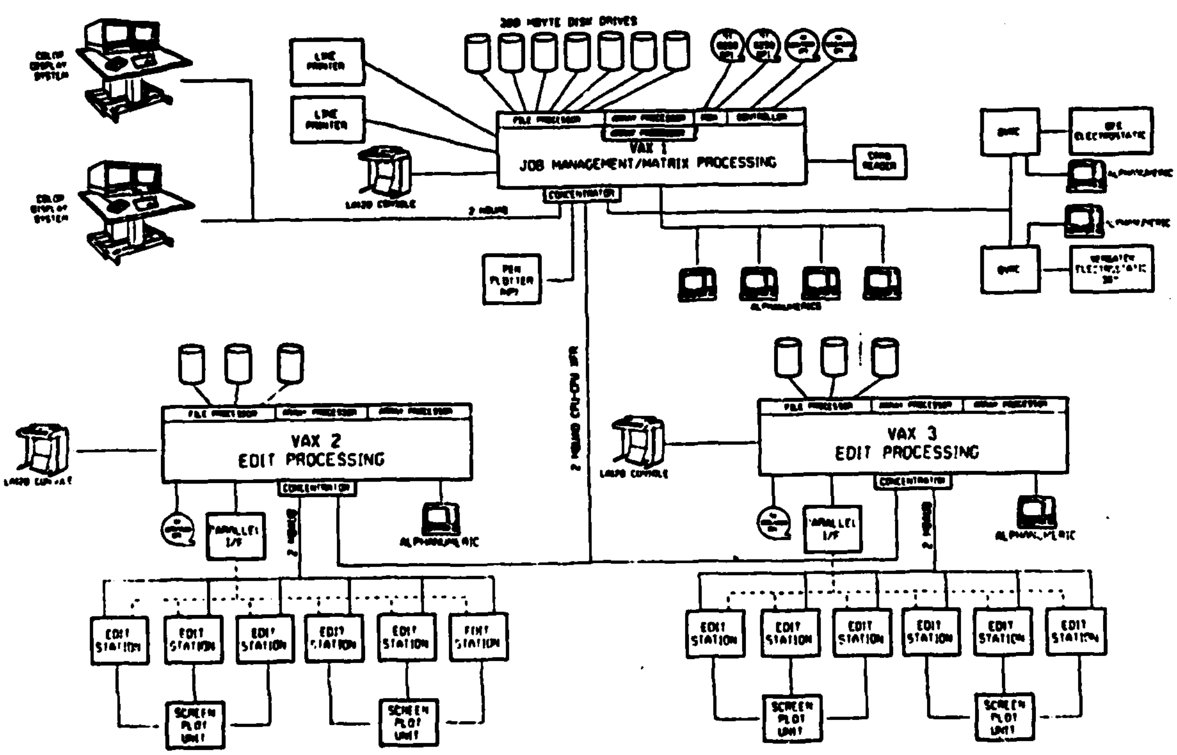

Figure 1

The main processing power of the system is provided by three VAX 11/780 computers, which are networked together to perform production control functions, matrix processing, plot generation and edit processing functions. The TES/EMPS computers are assisted in performing computationally intensive tasks, such as coordinate transformations, display generation, edit processing, and plotting by six array processors. The TES/EMPS on-line data base is maintained on thirteen 300MB disk drives with a capacity for over 400 DMA-Standard cells, in addition to operational software and virtual processing space. TES/EMPS plotting is performed on one of seven on-line plotters. There are two large format raster plotters for generating quality control plots, such as contour, profile, shaded relief, and gray scale; four screen plot units for generating a quick snapshot of the workstation display for future reference; and one eight color pen plotter for generating status reports and precision graphics. The interactive edit functions are performed at 12 high resolution (1024 X 1280), dual screen raster graphics workstations, where elevation data in both vector and matrix form are reviewed using a large number of matrix displays generated in real time through the array processor. Display and editing functions are performed on the dual screen display through operator interaction with a keyboard, floating menu and cursor and/or pop-up tutorials.

Work Flow and Processing

Job and File Management. Work flow through the TES/EMPS falls under control of Job and File Management software. Production managers at alphanumeric and graphic workstations use the Job and File Management system to set up projects as they enter the TES/EMPS, define processing steps and parameters for each data set, initiate sequences of job steps for each data set, and to monitor the progress of all work in the system.

Cartographic Data Post Processing. The processing of cartographic elevation data begins with an input operation, in which the vector data from the AGDS are read into the TES/EMPS and transformed into an internal file format for further processing. Once in internal format, the vector data go through a coordinate transformation from local table to a geographic coordinate system on WGS-72 datum . Following coordinate transformation, the vector data are processed through contour to grid software, where the contour, drain, ridge and other vector data are used to interpolate a geographic matrix of elevations at the desired data spacing. Following the contour to grid operation, an automatic anomaly/discrepancy detection is executed on the matrix data, and plots are generated to assist the cartographer in the identification of potential errors in the data. The matrix data and input vector data are then transferred to an interactive edit workstation for extensive review by the cartographer. Using the TES/EMPS dual screen workstation, the cartographer compares the elevation matrix to the input vector data to verify the validity of the process by checking the results visually. In the event of minor errors, corrections can be made directly to the matrix data; for major errors, the vector data can be corrected and reprocessed, producing a new elevation matrix. Following the interior edit and comparison with the vector data, the matrix data are interactively paneled to adjacent cells insuring continuity across cell and project boundaries. The final operations generate quality control plots, data set validation printouts, and DMA-Standard formatted tape with elevation matrix data for insertion into the DMA data bank and distribution to the user.

Photographic Data Post Processing. Photogrammetrically derived elevation data are input into the TES/EMPS as a series of models in a local coordinate system, where each model has several data sets consisting of an elevation matrix, a drain/ridge file, a water file, and a control elevation file. These data sets are processed through coordinate transformations and interpolations to derive new data sets in a geographic coordinate system with 3 arc second data spacing on the WGS 72 datum. The matrix is then locally adjusted to the drain/ridge data to maintain greater accuracy in the areas of valleys and tops. The photogrammetric models are then merged together, and the DMA-Standard cell is extracted. The DMA-Standard cell is then processed through the automatic anomaly/discrepancy detection software; quality control plots are generated; and the data are sent to the workstation for review and interactive edit. At the workstation, the data are displayed and anomalies are detected and corrected as necessary; water bodies are adjusted and merged with the matrix data; and vertical adjustments are made using control elevations to resolve biases between models. Prior to writing out the final DMA-Standard formatted tape, quality control plots and printouts are generated and evaluated to insure the quality and accuracy of the output.

UTM Data Post Processing. For generation of UTM or other non-standard formats, DMA-Standard digital terrain elevation data in a geographic coordinate system from the DMA data bank are used as input. As with all data read into the TES/EMPS, an internal file structure is created on input for further processing. The geographic matrix is processed through a coordinate transformation, and an interpolation is performed to create data at the desired spacing in the UTM coordinate system on a local datum. Following coordinate transformation and interpolation, data are merged, and the extracted UTM data are sent to the TES/EMPS workstation for panel checking against adjacent data sets and quality control review. Final quality control plots and printouts are generated prior to writing out the final formatted tape.

INTERACTIVE EDIT AND QUALITY CONTROL

Man/Machine Interface. To insure the quality, completeness, and accuracy of digital elevation products and increase productivity, HTC relies heavily on the interactive editing capabilities of the TES/EMPS. The TES/EMPS employs an array processor for rapid response generation of terrain display and edit functions, and uses a Motorola 68000 microprocessor in the workstation for dynamics, allowing the cartographer to rapidly pan, zoom and rotate the display. Digital elevation matrices reviewed on the TES/EMPS range in size from 800,000 to 1,444, 000 elevations and beyond; requiring rapid display generation and response to operator actions for efficient man/machine interface. In the TES/EMPS, displays are generated and edits are performed through an array processor within seconds of operator action.

The operator interface to the TES/EMPS is achieved through key board entries, menus on a digitizing surface, and tutorials displayed on the screen. Upon initiating an edit session, the operator is prompted to identify the data set to be edited through display of a queue of available jobs (see figure 2).

JOB STEP PROCESSING

VIRTUAL TERMINAL: 47 CPU: DMA3 DISK: OSA2 DIRECTORY: [264057]

NO.	STEP	SEQ	PROJ	PRI	NAME	STATUS
1	01	0005	120	01	EP_ES6	PARTIAL
2	01	0006	120	01	EP_ES6	PARTIAL
3	01	0007	120	01	EP_ES6	PARTIAL
4	02	0010	120	01	EP_ES6	PARTIAL
5	02	0011	120	01	EP_ES6	PARTIAL
6	01	0017	120	01	EP_ES6	PARTIAL
7	01	0018	120	01	EP_ES6	PARTIAL
8	01	0019	120	01	EP_ES6	INACTIVE

ACTIVATE STEP	REACTIVATE STEP	DISPLAY QUEUE	NEXT PAGE
REVIEW PACKET	POST COMPLETION	FAIL JOB STEP	EXIT

Figure 2

Upon selection of the job, the operator is led through the edit session with a series of menus and tutorials identifying the various options available for data display and editing. The majority of functions are available through interaction with the multi-button cursor, menus and displays providing rapid initiation of display and edit functions.

<u>Quality Control Displays</u>. Displays, such as contour, profile, and color scales, are similar to quality control plots utilized in the batch oriented systems. However, the TES/EMPS adds another dimension to terrain display and manipulation with the implementation of shaded relief displays, where the sun angle and azimuth can be readily modified to highlight discrepancies not previously identifiable. Additionally, each screen on the TES/EMPS workstation can be divided into four different windows (see Figure 3), providing a possibility for eight different displays of a data set for quality assurance review. In this case, any display available on the TES/EMPS may be presented in any of seven windows with the eigth window reserved for tutorials. Additional displays, such as an anaglyph stereo display, color shaded relief with contours overlaid, and gridded mesh displays with contours overlaid, assist in detecting subtle data discrepancies and anomalies. The TES/EMPS employs image processing techniques with convolution filters to highlight and correct anomalies, providing default filters or allowing the cartographer to define a specific filter for detecting and correcting anomalies having known data characteristics. For processing of cartographically derived elevation matrices, the TES/EMPS provides the

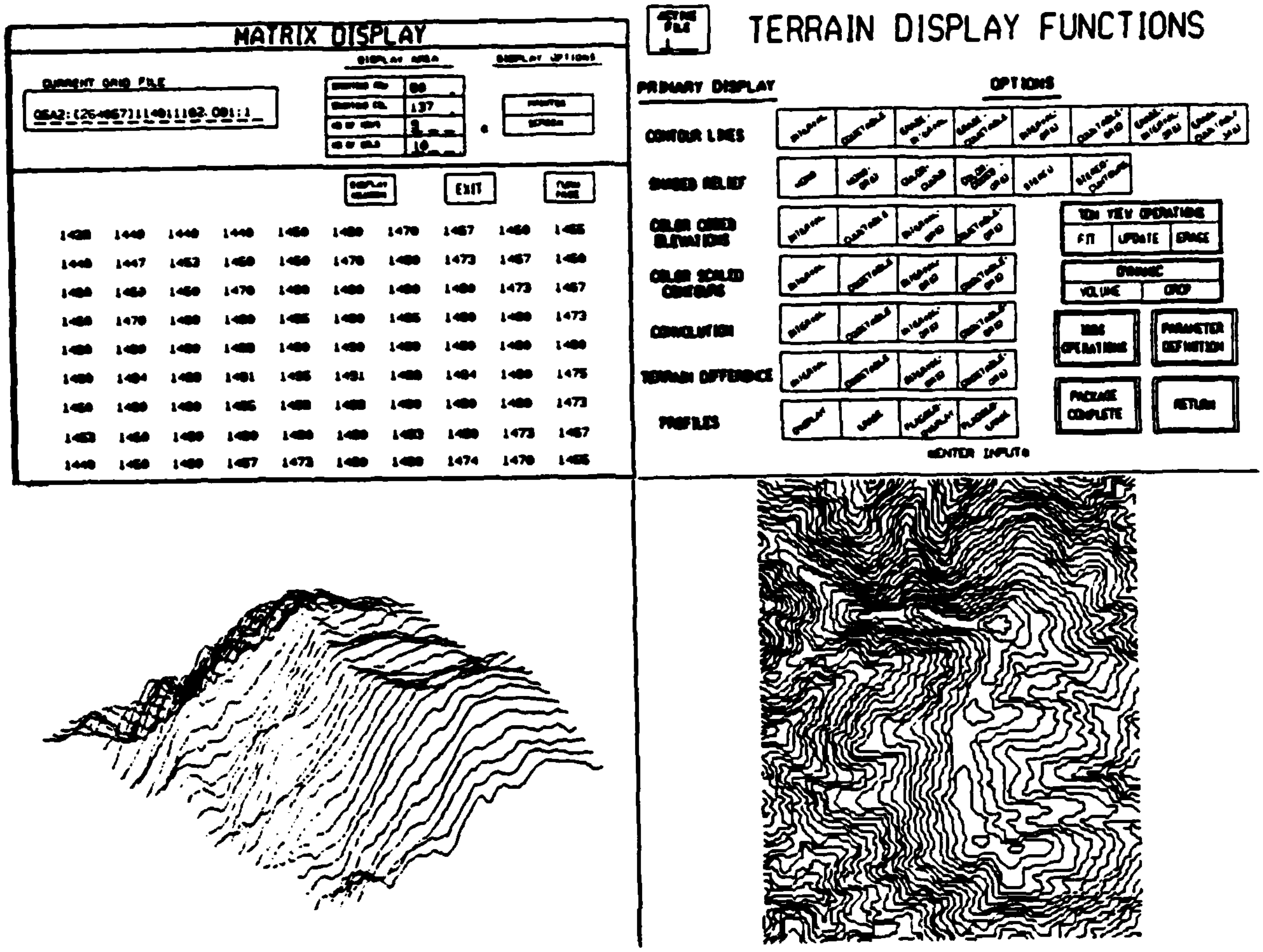

Figure 3

capability to review the interpolated matrix in conjunction with the digitized contour data, identify potential errors in the matrix, correct the error in the contour data, and generate a new error free matrix. As a quality control tool, the TES/EMPS provides the capability to down load a subset of the matrix into the workstation in a profile form, and dynamically pan, zoom and rotate the image providing a quick review of the data from all possible viewing angles (see Figure 4). These and many other review and edit capabilities are present on the TES/EMPS, contributing to greater quality and quantity of terrain elevation products produced at DMA.

<u>Interactive Edit Capabilities</u>. For editing of elevation matrices, the TES/EMPS has a large variety of interactive capabilities. In addition to conventional edit functions such as moving, deleting, replacing, and interpolating elevations, the TES/EMPS provides a variety of feathering routines for merging and paneling, convolution operators for smoothing, interactive routines for identifying and resolving blocked drains, and different interpolation schemes for unique problem areas. To assess the value of an edit operation, the TES/EMPS permits the cartographer to review the results of each edit function prior to acceptance by flashing between the uncorrected and corrected data. Aids are provided to the

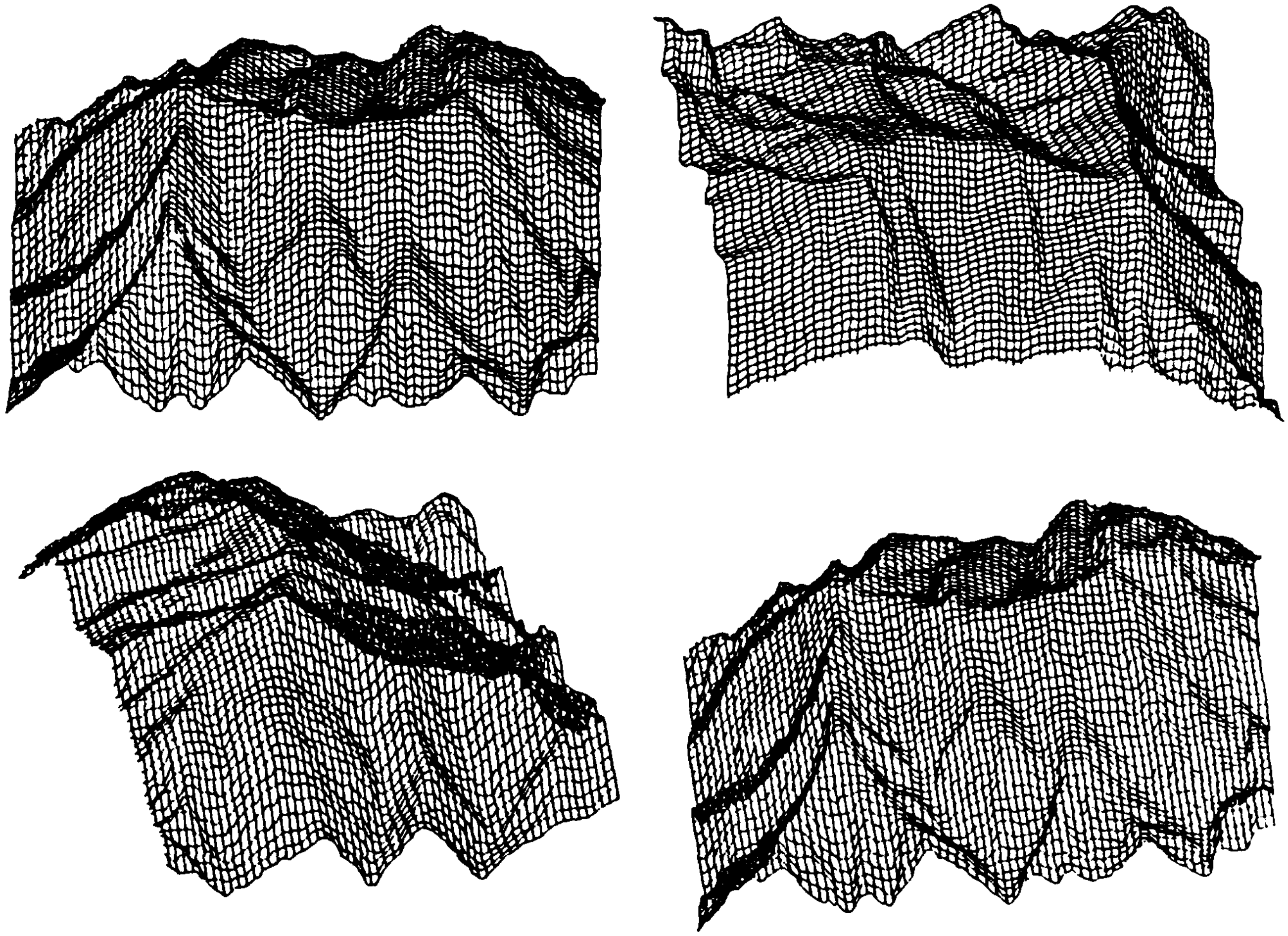

Figure 4

cartographer in deciding the appropriate edit action in the form of anomaly/discrepancy plots which identify potential errors, analysis functions which compare data sets to known control, and difference displays which compare overlapping data supporting merging and paneling operations.

CONCLUSION

A major challenge exists in maintaining production capabilities at the state-of-the-art to insure timely response to user demands for quality products. This paper has addressed one area in which DMA has exploited technology advancement, development, and the implementation of digital systems to satisfy a growing user community. Implementation of the TES/EMPS at DMA has resulted in increased production throughput in editing as well as matrix processing functions, such as coordinate transformations. Additionally, the quality of data has improved with the TES/EMPS advanced interactive display and edit capabilities. Shortcomings of the TES/EMPS exist in the overall size and complexity of the system. With over 50 menus and tutorials required for the 6

interactive editing scenarios, coupled with hundreds of optional parameters for edit and display functions, the transition from a batch to interactive environment is time consuming and difficult at best. Although initial training requires only two weeks, editing and processing efficiency are achieved only after months of continuous production experience. However, the slow startup costs are offset by the eventual productivity enhancement and quality benefits of implementing complex, yet flexible interactive systems. With growing demands for digital terrain elevation matrices the advancement of computer graphics and related technologies will play an increasingly important role in improving the quality and quantity of terrain elevation products.

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